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Hedonic Assessment of Coffee Processed with Pineapple Extract

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Abstract. *This study investigated the effects of steaming duration and pineapple peel-flesh extract proportions on the sensory acceptance of Arabica coffee processed with Subang pineapple extract. A Completely Randomized Design (CRD) was used with two factors: steaming duration (30, 60, and 90 minutes) and pineapple peel:flesh extract ratios (25:75, 50:50, and 75:25). Hedonic preference tests were conducted on selected sensory attributes of both ground and brewed coffee. Data were analyzed using ANOVA followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level. The result showed that steaming duration and pineapple extract ratio did not significantly affect the hedonic attributes of ground coffee. However, these factors influenced the color, aroma, body, acidity, and overall preference of brewed coffee. The optimal steaming duration was found to be between 30 and 60 minutes, with a pineapple peel extract ratio of pineapple peel and flesh extract of 75:25, resulting in the most preferred coffee according to panelists.*
Keywords: *Arabica coffee; hedonic preference test; steaming; Subang pineapple.*

1. Introduction

Coffee is one of the most widely consumed beverages globally, valued for its stimulating effects and distinctive sensory attributes (Shofinita *et al*., 2024). The two most widely known coffee species are Robusta (*Coffea canephora*) and Arabica (*Coffea arabica*). Arabica is typically preferred by consumers because of its sweeter flavor, fruity fragrance, and higher acidity. In contrast, Robusta is recognized for its more bitter taste, with lower levels of acidity and sweetness (Šeremet *et al*., 2022). Caffeine is a natural stimulant found in coffee beans; it acts on the central nervous system to reduce fatigue and increase alertness. However, excessive caffeine intake has been associated with adverse health effects such as insomnia, hypertension, anxiety (Hariyadi *et al*., 2024; Umakanthan & Mathi, 2022), increased heart rate, and digestive issues, especially in sensitive individuals. Caffeine typically makes up about 1–2% of the weight of raw coffee beans, and, due to its adenosine-like structure, it influences the central nervous system (Lee & Kim,

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2023). People with certain medical conditions, such as hypertension, heart disease, and gastroesophageal reflux, and even pregnant women, are often advised to limit caffeine consumption to below 200 mg per day. This has led to a growing demand for decaffeinated coffee, which retains the desirable flavor and aroma while reducing caffeine content.

Traditional decaffeination methods often involve chemical solvents or supercritical CO_2, which may compromise the sensory quality of coffee or raise safety concerns. As a response, enzymatic decaffeination using natural proteolytic enzymes has emerged as a promising alternative. Bromelain, a protease enzyme found in pineapple (*Ananas comosus*), has shown potential in breaking down protein structure in coffee beans, facilitating caffeine release during processing (Muhsinin *et al*., 2021). Crude bromelain extracted from pineapple peels significantly reduces caffeine content in Robusta coffee, achieving up to 97% reduction when using 80% extract concentration and 36 hours of fermentation (Hariyadi *et al*., 2024). The Subang pineapple is a local Indonesian cultivar known for its high bromelain activity and has been explored for various food applications, including enzymatic treatments. Moreover, pineapple peels, often considered waste, contain significant amounts of bromelain and other bioactive compounds, making them a sustainable resource for food processing (Kumar, 2021).

In this study, the coffee used is Arabica coffee from Ciater, a highland region in West Java known for producing beans with bright acidity and floral notes. Steaming is a pre-treatment method that can influence enzyme penetration and substrate accessibility in coffee beans (Kalschne *et al*., 2019). In brewed Arabica coffee, Anggriawan *et al*. (2020) evaluated an inverse correlation between steaming time (0, 20, 40, 60, and 80 min) and caffeine content, with the lowest caffeine concentration (0.84 g/100 g) achieved at 80 minutes. The duration of steaming may affect the efficiency of bromelain activity and, consequently, the decaffeination process and sensory outcomes. However, limited studies have investigated the combined effect of steaming duration and pineapple peel:flesh ratio on the sensory acceptance of decaffeinated coffee. The beans were roasted at a medium level, which is commonly preferred for balancing acidity, body, and flavor complexity, making it suitable for sensory evaluation (Šeremet *et al*., 2022). This study aimed to evaluate the effect of steaming duration and the proportion of Subang pineapple (peel and flesh) on the hedonic preference of decaffeinated coffee, both in grounded and brewed forms. This study contributes to the development of natural, consumer-acceptable decaffeinated coffee products and promotes the valorization of agricultural products.

2. Material and Methods

2.1. Raw materials and preparation of coffee beans and Subang pineapples

Arabica coffee was obtained from coffee farmers in Ciater, Subang Regency, Indonesia. Coffee beans were sieved and sorted to remove impurities and rotten beans. Subang pineapples were obtained from a pineapple farmer in Jalancagak, Subang Regency, with physiological maturity, which is characterized by yellowish skin color covering about ¾ of the fruit, a noticeable distinct aroma, and soft yet firm flesh texture. The pineapples are peeled and thoroughly washed with clean water to remove dirt and surface contaminants. The fruit and peel are cut into smaller pieces and crushed using a chopper with medium speed to release juice and pulp. The crushed material is filtered using a fine mesh or cheesecloth to separate the liquid extract from the solid residue.

2.2. Decaffeination process

Selected Arabica green beans from Ciater were washed thoroughly with clean water to remove impurities. The washed beans were steamed at three different durations (P1: 30 minutes; P2: 60 minutes; P3: 90 minutes). Steaming was conducted to soften the bean structure and enhance enzyme penetration. Steamed coffee beans were soaked in the pineapple extract according to the designated proportions (N1= 25% peel:75% fruit; N2= 50% peel:50% fruit; N3= 75% peel:25% fruit) for 24 hours. The soaking facilitates enzymatic decaffeination through bromelain activity (Utama *et al*., 2022). After soaking, the beans were washed and dried in a dehydrator to reduce moisture content. The dried beans were roasted to a medium level with a charge temperature of 200°C (drop of ± 210-212°C) for 12 minutes, suitable for balancing acidity, body, and flavor. Roasted beans were ground and brewed for sensory evaluation.

2.3. Measurement of hedonic preference

The hedonic test was conducted to evaluate the sensory preference of decaffeinated coffee samples. The test involved 33 untrained panelists who were familiar with coffee consumption, following a screening process prior to recruitment. Prior to the sensory evaluation, they completed a self-administered questionnaire collecting socio-demographic information and coffee consumption patterns. The sensory tests took place in a controlled laboratory setting, with each participant seated in a separate booth under white lighting. The sensory evaluation was conducted in two stages, involving ground coffee and brewed coffee samples. In the first stage, each panelist assessed the ground coffee based on sensory attributes of color, fragrance, and fineness. The samples were presented in 100 mL glass cups labeled with randomly assigned three-digit codes, and the presentation order was randomized for each panelist. In the second stage, approximately fifty milliliters of coffee prepared at a concentration of 500 g/L were served at 70°C in 100 mL glass cups labeled with randomly assigned three-digit codes (Kalschne *et al*., 2019). The sample presentation sequence was randomized for each participant, and they were instructed to cleanse their palate with water before tasting each sample. Each panelist evaluated brewed coffee at 93-96°C (cupping method) based on color, aroma, flavor, body, acidity, aftertaste, and overall preference. A sensory control (untreated coffee) was not included because the objective of this study was to compare differences among decaffeination treatments. The description of each sensory attribute evaluated in the hedonic test is presented in Table 1.

Table 1. Description of Sensory Attribute of Coffee

No	Sensory Attributes	Description
1	Ground coffee	
	a. Color	Various hues of ground coffee
	b. Fragrance	The smell of fresh ground, dry coffee beans
	c. Fineness	The size of the coffee bean particles
2	Brewed coffee	
	a. Color	Various hues of brewed coffee, influenced by roast level, brewing temperature, and extraction process
	b. Aroma	The scent that is released from the coffee once it has been brewed with hot water
	c. Flavor	Combination of aroma and taste
	d. Body	Viscosity of the solution
	e. Acidity	A pleasant, bright, and tangy sensation comes from organic acids naturally present in the beans
	f. Aftertaste	Taste left in the mouth
	g. Overall	The taster's subjective, holistic appraisal of the coffee

Panelists rated their preference using a 5-point Likert scale (1 = strongly dislike, 2 = dislike, 3 = slightly like, 4 = like, 5 = strongly like). The scores given by the panelists were used to determine the preference of each treatment.

The average score for each sensory attribute was calculated using the following formula (1).

$$\text{Mean Score} = \frac{\text{Total Score}}{\text{Number of Respondents}} \qquad (1)$$

The range of assessments for each Likert scale category is calculated using the following formula (2).

$$\text{Category Range} = \frac{\text{Maximum scale value} - \text{Minimum scale value}}{\text{Number of Likert categories}} \qquad (2)$$

In this study, the Likert scale consists of 5 categories, with a minimum score of 1 and a maximum score of 5. Therefore, the range for each category is calculated as:

$CR = (5 - 1) / 5 = 0.8$

This range helps to interpret the average scores by categorizing them into levels of preference. Based on this interval, the interpretation of mean scores for each sensory attribute is presented in Table 2.

Table 2. Interpretation of Hedonic Score Based on Likert Scale

Interval Score	Preference Level
1.0 – 1.8	Strongly Dislike
1.9 – 2.6	Dislike
2.7 – 3.4	Slightly Like
3.5 – 4.2	Like
4.3 – 5.0	Strongly Like

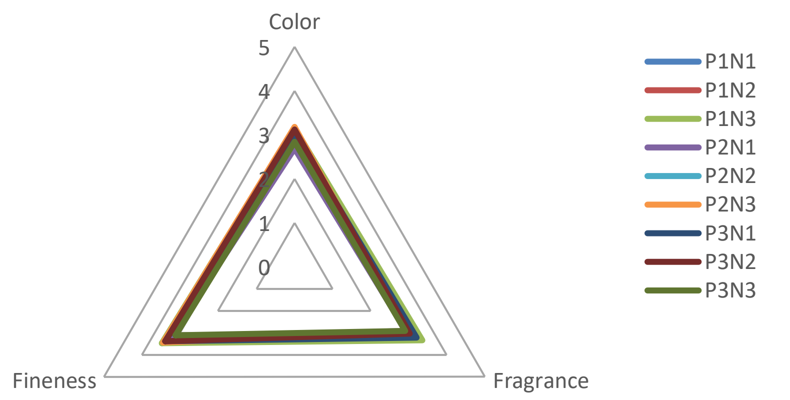
2.4. Measurement of hedonic preference

Data were analyzed using two-way Analysis of Variance (ANOVA), and post hoc analysis Duncan's Multiple Range Test (DMRT) was performed using the SPSS Statistics 22.0 program (IBM, Armonk, NY, USA) with a significance level of α = 5% to identify significant differences among treatments.

3. Results and Discussion

3.1. Hedonic preference of ground coffee

Hedonic testing was conducted on decaffeinated ground coffee with treatments involving variations in steaming duration and the proportion of pineapple peel extract to pineapple juice. The results of the hedonic test are shown in Figure 1. Overall, the levels of preference for the attributes of color, fragrance, and fineness of the decaffeinated coffee ground did not differ significantly.



Note: The asterisk (*) denotes a significant difference, which is explained for each respective attribute

Figure 1. Hedonic preference of ground decaffeinated coffee

3.1.1. Color

Color evaluation was conducted to determine the effect of the decaffeination process on the appearance of the ground coffee. The results of the hedonic test on the color of the decaffeinated ground coffee are presented in Table 3. Table 3 showed that the highest color preference score was obtained in treatment P2N3 (steaming for 60 minutes and a pineapple peel extract to pineapple juice ratio of 25:75), with a score of 3.18 (slightly like), while the lowest score was found in treatment P2N1 (steaming for 60 minutes and a ratio of 75:25), with a score of 2.70 (slightly like).

Table 3. Preference level for the color of decaffeinated ground coffee

Treatment		Hedonic Preference		
Steaming Duration (P)	Extract Pineapple Peel: Flesh (N)	Color	Fragrance	Fineness
P1 (30 minutes)	N1 25:75	3.06 ± 1.02	3.12 ± 0.96	3.30 ± 0.98
	N2 50:50	2.97 ± 0.88	3.15 ± 1.03	3.27 ± 0.84
	N3 75:25	3.15 ± 1.27	3.36 ± 0.89	3.48 ± 0.97
P2 (60 minutes)	N1 25:75	2.70 ± 0.95	2.93 ± 0.96	3.24 ± 0.83
	N2 50:50	3.09 ± 0.94	3.03 ± 0.85	3.39 ± 0.83
	N3 75:25	3.18 ± 1.18	2.96 ± 0.91	3.45 ± 0.90
P3 (90 minutes)	N1 25:75	3.03 ± 0.76	3.21 ± 0.99	3.39 ± 0.96
	N2 50:50	3.12 ± 1.11	3.03 ± 0.85	3.39 ± 0.99
	N3 75:25	2.84 ± 0.97	2.91 ± 0.95	3.12 ± 1.02

The analysis of variance indicated that the differences in steaming duration and pineapple extract proportion had no significant effect on the color of the resulting decaffeinated ground coffee. The color of ground coffee is a visual characteristic that reflects the roasting level, bean quality, and processing method. The medium roasting level applied across all treatments resulted in a medium brown color in the decaffeinated coffee ground. Additionally, the decaffeination process may remove some phenolic compounds and other substances that influence the color of coffee ground during roasting. Decaffeinated coffee tends to produce lighter-colored ground compared to regular coffee roasted for a longer time (Rubiyanti & Yulia, 2024).

The relatively low preference scores may be influenced by the panelists' drinking habits, as they typically consume medium to dark or dark roast coffee, which has a dark brown to blackish color. The color of coffee beans during roasting is closely linked to both the duration and temperature of the process. As roasting time increases and temperature rises, the beans become darker, making color a reliable indicator for determining the completion of roasting (Ribeiro *et al*., 2013). Coffee beans undergo chemical and physical changes during decaffeination, which can reduce the intensity of Maillard and caramelization reactions during roasting, resulting in a lighter ground color. Decaffeinated coffee is often roasted more lightly to preserve the flavor that has already been reduced due to the decaffeination process. Jeszka-Skowron *et al*. (2020) reported that pre-steaming and decaffeination weaken the bean matrix and reduce Maillard browning intensity, producing roasted beans with noticeably higher lightness. Similarly, water-decaffeinated Arabica coffee exhibited an increase in L* values from approximately 21-22 in regular roasted beans to 25-27 after decaffeination, corresponding to a 15-20% increase in whiteness (Farah *et al*., 2006).

3.1.2. Fragrance

The fragrance of ground coffee refers to the aroma perceived from decaffeinated ground coffee before brewing. Fragrance is one of the key attributes in sensory evaluation of coffee, providing an initial indication of the quality and characteristics of the coffee beans.

The results of the hedonic test on the fragrance of decaffeinated ground coffee are presented in Table 3. Based on Table 3, the highest fragrance preference score was obtained in treatment P1N3 (steaming for 30 minutes and a pineapple peel extract to pineapple juice ratio of 75:25), with a score of 3.36 (slightly like), while the lowest score was found in treatment P2N3, with a score of 2.91 (slightly like).

Analysis of variance showed that the steaming duration and pineapple extract proportion did not significantly affect the fragrance preference of the decaffeinated ground coffee. This finding differs from the study by Oktadina *et al.* (2013), which reported a significant difference in coffee aroma due to the activity of bromelain enzymes from grated pineapple, which help reduce caffeine content and enhance the aroma of ground coffee. Grated pineapple was used at relatively high concentration (40-80%) with added water, creating a moist fermentation-like environment. Such conditions may enhance enzymatic hydrolysis of protein matrices and facilitate the release of volatile aroma precursors. In contrast, this study used specific peel-to-flesh extract ratios, where the presence of peel introduces tannins, pectins, and phenolic compounds known to inhibit bromelain activity. Steaming prior to soaking may also have partially denatured the enzyme or altered bean surface permeability, reducing its effectiveness. Furthermore, differences in extraction intensity, contact time, moisture content, and roasting behavior can cause variations in aroma precursor formation.

3.1.3. Fineness

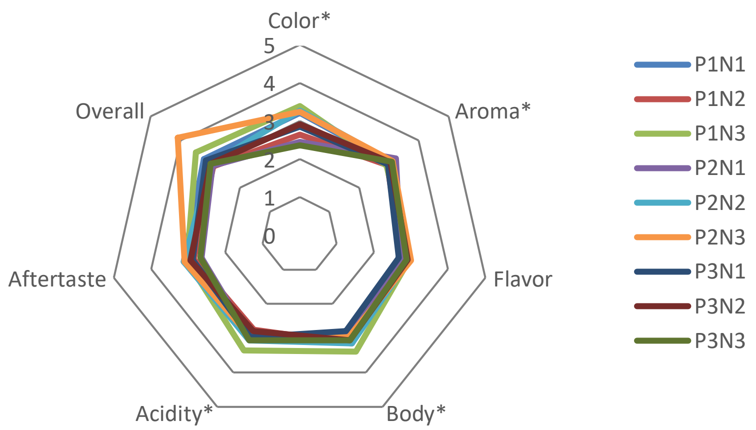
Fineness of ground coffee refers to the particle size of ground coffee after the grinding process. It is one of the key physical parameters that affects flavor extraction, aroma, and the strength of the brewed coffee. The results of the hedonic test on the fineness of decaffeinated ground coffee are presented in Table 3. The highest preference score for fineness was observed in the treatment with 30 minutes of steaming and a pineapple peel extract to pineapple juice ratio of 75:25 (P1N3), with a score of 3.48, indicating that this powder texture was the most preferred by the panelists. The lowest score was obtained in the treatment with 90 minutes of steaming and the same ratio (P3N3), with a score of 3.12 (slightly like).

Based on the analysis of variance, the steaming duration and pineapple extract ratio did not significantly affect the fineness of the decaffeinated ground coffee. Longer steaming tended to reduce preference scores, while higher proportions of pineapple peel extract tended to result in higher scores. This may be due to changes in the physical structure of the coffee beans caused by prolonged steaming. These results are consistent with previous research showing that pineapple peel extract treatment can improve the organoleptic scores for aroma and fineness of ground coffee (Noviar *et al*., 2016).

The particle size in ground coffee is primarily governed by the mechanical properties of roasted beans, such as hardness, brittleness, and fracture behavior, which were likely not substantially altered by the steaming or pineapple peel extract treatments. Previous studies have shown that roast-induced structural integrity, not mild pre-treatments, is the dominant factor determining grindability and particle size distribution (Baggenstoss *et al*., 2008). Gloess *et al*. (2013) also explained that steaming at moderate intensities mainly affects surface moisture and does not produce deep structural changes within the bean matrix.

3.2. Hedonic preference of brewed coffee

Hedonic testing was conducted on brewed decaffeinated coffee with treatments involving variations in steaming duration and the proportion of pineapple peel extract to pineapple juice. The results of the hedonic test are presented in Figure 2.



Note: The asterisk (*) denotes a significant difference, which is explained for each respective attribute

Figure 2. Hedonic preference of brewed decaffeinated coffee

3.2.1. Color

The color of brewed coffee is a visual characteristic of the coffee liquid after brewing, influenced by the type of coffee, roasting level, brewing method, and the concentration of ground coffee used. Color serves as an indicator of both sensory and chemical quality in brewed coffee. The results of the preference test for the color of brewed decaffeinated coffee are presented in Table 4.

As shown in Table 4, the steaming duration and pineapple extract ratio had a significant effect on the color preference of brewed decaffeinated coffee. The color preference of brewed decaffeinated coffee followed a consistent trend. Shorter steaming duration (P1) produced higher preference scores, especially when combined with a higher pineapple peel ratio (N3), with P1N3 reaching the highest score of 3.39 (slightly liked). In contrast, increasing steaming duration from 30 to 90 minutes caused a gradual decline in preference across all extract ratios, with treatment P3N3 showing the lowest score of 2.36 (dislike). This indicates that prolonged steaming produces a duller, less appealing brew color.

Within each steaming level, increasing the pineapple peel proportion generally improved color scores. This suggests that pineapple extract contributed to a brighter brew color when steaming remained moderate. Excessive steaming tended to result in lower preference scores due to the degradation of compounds contributing to color, such as oxidation of melanoidin compounds and degradation of chlorogenic acid (Jeszka-Skowron *et al.*, 2020). Meanwhile, the use of pineapple extract may have enhanced pigment breakdown under heat due to the acidic and enzymatic properties of pineapple (Hariyadi *et al.*, 2024), improving color only when steaming was not excessive.

Table 4. Preference Level for the Color of Brewed Decaffeinated Coffee

Treatment		Hedonic Preference
Steaming Duration (P)	Extract Pineapple Peel: Flesh (N)	
P1 (30 minutes)	N1 25:75	$3.21^{bc} \pm 0.89$
	N2 50:50	$2.64^{abc} \pm 0.85$
	N3 75:25	$3.39^{c} \pm 1.14$
P2 (60 minutes)	N1 25:75	$2.45^{ab} \pm 0.90$
	N2 50:50	$3.27^{c} \pm 0.91$
	N3 75:25	$3.24^{c} \pm 1.09$
P3 (90 minutes)	N1 25:75	$2.85^{abc} \pm 0.93$
	N2 50:50	$2.91^{abc} \pm 1.1$
	N3 75:25	$2.36^{a} \pm 1.08$

Note: Different notations following the numbers indicate significant differences at α = 5%.

3.2.2. Aroma

Aroma refers to the complexity of scents perceived from coffee during brewing. It is one of the most important sensory attributes in determining coffee quality. The preference level for the aroma of brewed decaffeinated coffee can be seen in Table 5.

The preference scores for the aroma of brewed decaffeinated coffee were significantly influenced by both steaming duration and the pineapple peel extract ratio, as shown in Table 5. The highest aroma preference occurred in treatment P1N3 (30 minutes of steaming with a 75:25 pineapple peel-to-flesh extract ratio) with a score of 3.24 (slightly like), which likely resulted from the preservation of key volatile compounds during the shorter steaming duration. Coffee aroma arises from the reaction between ground coffee and hot water during brewing. Volatile components and gases evaporate as the coffee is brewed (Anggraini, 2024). Coffee aroma is derived from hundreds of volatile compounds formed during processing, especially roasting, such as furans, pyrazines, aldehydes, ketones, volatile organic acids, and sulphur compounds. These compounds contribute to caramel, sweet, roasted, nutty, earthy, fruity, floral, fresh acidic, and other aroma notes.

Table 5. Preference Level for the Aroma of Brewed Decaffeinated Coffee

Treatment		Hedonic Preference
Steaming Duration (P)	Extract Pineapple Peel: Flesh (N)	
P1 (30 minutes)	N1 25:75	$3.06^{ab} \pm 1.08$
	N2 50:50	$2.94^{ab} \pm 0.78$
	N3 75:25	$3.24^{b} \pm 0.90$
P2 (60 minutes)	N1 25:75	$2.73^{a} \pm 1.00$
	N2 50:50	$3.09^{ab} \pm 0.84$
	N3 75:25	$3.12^{ab} \pm 0.85$
P3 (90 minutes)	N1 25:75	$2.97^{ab} \pm 0.80$
	N2 50:50	$3.06^{ab} \pm 0.86$
	N3 75:25	$3.09^{ab} \pm 0.87$

Note: Different notations following the numbers indicate significant differences at α = 5%.

Aroma plays a crucial role in determining coffee quality, so it is essential to minimize any alterations in aroma during the decaffeination process (Lee & Kim, 2023). Aroma from treatments involving 60–90 minutes of steaming was less preferred, likely due to the degradation of aroma compounds that are sensitive to temperature and processing duration. The coffee volatiles are highly susceptible to thermal degradation, with elevated temperatures accelerating the breakdown and evaporative loss of aroma-forming compounds (Dippong *et al.*, 2022). The use of higher concentrations of pineapple peel extract appears to enhance aroma complexity through the contribution of compounds from the peel, such as esters and organic acids, although the effect is optimal only with shorter steaming durations. Volatile esters, alcohols, aldehydes, and ketones contributed fruity, sweet, and floral aroma notes, but these compounds are themselves heat-labile and degrade under prolonged thermal exposure (Hikal *et al.*, 2022). This aligns with the prior research showing that steaming duration affects the softening of coffee bean tissues, which in turn influences the extraction of color and aroma compounds in robusta coffee (Wijaya & Yuwono, 2015).

3.2.3. Flavor

Flavor describes the overall taste impression perceived in the mouth during and after drinking coffee, which is a combination of basic taste and aroma. Flavor is the most complex and important sensory attribute in coffee quality evaluation. The results of the hedonic test for the flavor of brewed decaffeinated coffee are presented in Table 6.

Based on Table 6, steaming for 60 minutes with a pineapple extract ratio of 75:25 (P2P3) resulted in the highest flavor preference score of 3.00 (slightly like), while the lowest score was obtained in treatment N3P1 with a score of 2.67. According to ANOVA calculations, the steaming duration and pineapple extract ratio did not significantly affect the flavor of brewed decaffeinated coffee. This lack of significance is likely due to the relative stability of key flavor-forming compounds in coffee, such as chlorogenic acids, caffeine, and melanoidins, which are less sensitive to heat-induced changes than volatile aroma compounds and therefore do not vary substantially under steaming durations of 30–90 minutes. Coffee flavor is shaped primarily by non-volatile compounds generated during roasting, while many volatile compounds that differentiate aroma—not flavor—are more susceptible to thermal degradation at elevated temperatures (Dippong *et al*., 2022).

As a result, although pineapple peel extract contains esters, aldehydes, ketones, and organic acids that enhance aromatic complexity (Hikal *et al*., 2022; Nordin *et al*., 2023), these constituents contribute minimally to taste perception and therefore do not meaningfully modify overall flavor. Additionally, decaffeination and steaming processes can reduce overall flavor complexity, producing a flatter taste profile that minimizes perceptible differences among treatments. The combination of flavor-stabilizing compounds, the limited role of pineapple-derived volatiles in taste perception, and higher sensory variability associated with flavor evaluation likely contributed to the absence of statistically significant differences across treatments.

Table 6. Preference Level for the Flavor of Brewed Decaffeinated Coffee

Treatment		Hedonic Preference
Steaming Duration (P)	Extract Pineapple Peel: Flesh (N)	
P1 (30 minutes)	N1 25:75	2.91 ± 0.91
	N2 50:50	2.75 ± 0.90
	N3 75:25	2.93 ± 1.05
P2 (60 minutes)	N1 25:75	2.73 ± 0.91
	N2 50:50	2.94 ± 0.78
	N3 75:25	3.00 ± 0.96
P3 (90 minutes)	N1 25:75	2.67 ± 0.88
	N2 50:50	2.91 ± 0.84
	N3 75:25	2.88 ± 0.96

3.2.4. Body (Texture/Thickness)

The body of brewed coffee refers to the physical sensation felt in the mouth when drinking coffee, particularly related to the thickness, weight, and texture of the coffee liquid. The panelists' preference levels for the body of brewed decaffeinated coffee are presented in Table 7.

Table 7 showed that treatments with longer steaming durations and higher proportions of pineapple peel extract, particularly P1N3 and P3N3, received higher preference scores compared to treatments with lower peel extract ratios or shorter steaming durations. Based on ANOVA analysis, the steaming duration and pineapple extract ratio significantly affected the panelists' preference for the body of brewed coffee. This trend suggests that the steaming process and peel proportion influenced the extraction and retention of body-forming compounds.

Table 7. Preference Level for the Body of Brewed Decaffeinated Coffee

Treatment			Hedonic Preference
Steaming Duration (P)	Extract Pineapple Peel: Flesh (N)		
P1 (30 minutes)	N1	25:75	$2.94^{ab} \pm 0.93$
	N2	50:50	$3.15^{ab} \pm 0.79$
	N3	75:25	$3.39^{b} \pm 0.86$
P2 (60 minutes)	N1	25:75	$2.85^{a} \pm 0.87$
	N2	50:50	$3.15^{ab} \pm 0.75$
	N3	75:25	$2.97^{ab} \pm 0.84$
P3 (90 minutes)	N1	25:75	$2.79^{a} \pm 0.82$
	N2	50:50	$3.06^{ab} \pm 0.86$
	N3	75:25	$3.06^{ab} \pm 0.74$

Note: Different notations following the numbers indicate significant differences at α = 5%.

Body is one of the key attributes in sensory evaluation, as it provides the impression of a "full" or "light" coffee experience. The body of brewed coffee can be influenced by factors such as coffee bean type, oil content, dissolved compounds, decaffeination process, steaming duration, coffee concentration, and brewing method. Arabica coffee tends to have a lighter body compared to Robusta (Wijaya & Yuwono, 2015). The trend is likely due to increased extraction of body-forming compounds such as lipids, polysaccharides, and melanoidins, which contribute to viscosity and a fuller mouthfeel. Pineapple peel also contains polysaccharides and phenolic components with water-binding and viscosity-enhancing properties, explaining why higher peel ratios further improved body perception (Cardona *et al*., 2022; Hadidi *et al*., 2020). Panelists therefore preferred treatments combining longer steaming and greater peel extract proportions because these conditions enhanced the release of both coffee-derived oils and peel-derived structural compounds, producing a richer and smoother body.

3.2.5. Acidity

Acidity in brewed coffee refers to the sour taste sensation perceived on the tongue while drinking coffee, which originates from natural organic acids in the coffee beans. Acidity reflects the freshness and complexity of coffee flavor.

Table 8. Preference Level for Acidity of Brewed Decaffeinated Coffee

Treatment			Hedonic Preference
Steaming Duration (P)	Extract Pineapple Peel: Flesh (N)		
P1 (30 minutes)	N1	25:75	$2.91^{ab} \pm 1.01$
	N2	50:50	$2.76^{a} \pm 0.86$
	N3	75:25	$3.36^{b} \pm 0.92$
P2 (60 minutes)	N1	25:75	$3.00^{ab} \pm 0.82$
	N2	50:50	$3.06^{ab} \pm 0.96$
	N3	75:25	$2.97^{ab} \pm 0.80$
P3 (90 minutes)	N1	25:75	$2.97^{ab} \pm 1.01$
	N2	50:50	$2.79^{a} \pm 0.73$
	N3	75:25	$3.06^{ab} \pm 0.86$

Note: Different notations following the numbers indicate significant differences at α = 5%

Table 8 showed that both steaming duration and pineapple extract ratio significantly affected the acidity preference of brewed decaffeinated coffee. Treatment P1N3 resulted in the highest acidity preference score of 3.36 (slightly like), while treatment P1N2 had the lowest score of 2.76 (slightly like). Higher acidity occurred in shorter steaming treatments with higher pineapple extract ratios, likely because moderate heating better preserved organic acids that contribute to bright acidity. Recent studies confirm that chlorogenic acids and other coffee organic acids are thermolabile, undergoing rapid degradation when exposed to prolonged heat, elevated temperatures, or unfavorable pH conditions (Liu *et al*., 2021). Similarly, thermal stability analysis shows that degradation of mono- and dichlorogenic acids can begin at relatively low temperatures, with increasing heat exposure accelerating their loss (Grzelczyk *et al*., 2022).

As steaming time increases, the cumulative heat exposure is likely to reduce intrinsic acidity, thereby diminishing the enhancing effect of citric- and malic-acid-rich pineapple extract. Progressive thermal processing consistently decreases total chlorogenic acids across roast levels, reinforcing the sensitivity of these compounds to heat (Yeager *et al*., 2023). Thus, the highest acidity preference observed in short-duration steaming with higher pineapple extract ratios aligns with known thermal degradation patterns of organic acids in coffee.

3.2.6. Aftertaste

Aftertaste is the lingering taste sensation in the mouth after swallowing coffee. It may fade quickly or persist with various flavor notes such as bitter, sweet, sour, and others. The hedonic test results for the aftertaste of brewed decaffeinated coffee are shown in Table 9.

Table 9. Preference Level for Aftertaste of Brewed Decaffeinated Coffee

Treatment		Hedonic Preference
Steaming Duration (P)	Extract Pineapple Peel: Flesh (N)	
P1 (30 minutes)	N1 25:75	3.12 ± 1.05
	N2 50:50	2.85 ± 0.90
	N3 75:25	3.03 ± 1.07
P2 (60 minutes)	N1 25:75	2.63 ± 0.89
	N2 50:50	3.12 ± 0.96
	N3 75:25	3.09 ± 0.84
P3 (90 minutes)	N1 25:75	2.88 ± 1.02
	N2 50:50	2.94 ± 0.89
	N3 75:25	2.67 ± 0.92

Table 9 showed that steaming duration and pineapple extract ratio did not significantly affect the aftertaste of brewed decaffeinated coffee. Preference scores ranged from 2.67 to 3.12, indicating panelists rated the aftertaste between dislike and slightly like. Some panelists described the aftertaste as dry in the throat. This astringent sensation may be related to chemical composition, the decaffeination process, and coffee concentration. This observation was based solely on qualitative comments from panelists during sensory testing and was not supported by measured chemical data in this study. Recent studies have demonstrated that astringency in coffee can arise from phenolic-rich melanoidin fractions and other non-volatile compounds capable of eliciting tactile sensations such as dryness and roughness in the oral cavity (Linne *et al.*, 2025). Decaffeination can reduce not only caffeine but also flavor compounds and essential oils that contribute to a smooth and pleasant aftertaste (Sinaga *et al.*, 2021). The loss of compounds such as lipids and chlorogenic acid may cause a dry or rough mouthfeel (Šeremet *et al.*, 2022; Shofinita *et al.*, 2024).

3.2.7. Overall

"Overall" refers to the general assessment of coffee quality (Sinaga *et al.*, 2021). The preference scores for overall impression of brewed decaffeinated coffee are presented in Table 10.

Table 10 shows a clear trend in which the overall preference for brewed decaffeinated coffee increases with longer steaming duration up to 60 minutes (P2), after which the preference declines at 90 minutes (P3). The highest liking in treatment P2N3 (60 minutes steaming, 75:25 ratio) had the score of 4.09 (like), suggesting that moderate steaming optimizes the balances of aroma, acidity, and body, while the added pineapple peel extract enhances complexity and sweetness. The combination of 60-minute steaming and a higher pineapple peel extract ratio produced decaffeinated coffee that was preferred by panelists. In contrast, shorter steaming (P1) or excessively long steaming (P3) produces less favorable sensory profiles, likely due to insufficient flavor development or degradation of key compounds. Recent studies confirm that optimal thermal processing enhances coffee's sensory harmony, whereas excessive heat reduces chlorogenic acids, volatiles, and flavor-active constituents (Jeszka-Skowron *et al.*, 2020; Linne *et al.*, 2025; Sinaga *et al.*, 2021).

Table 10. Overall Preference Level for Brewed Decaffeinated Coffee

Treatment		Hedonic Preference
Steaming Duration (P)	Extract Pineapple Peel: Flesh (N)	
P1 (30 minutes)	N1 25:75	$3.21^{ab} \pm 0.96$
	N2 50:50	$2.91^{a} \pm 0.72$
	N3 75:25	$3.48^{ab} \pm 0.93$
P2 (60 minutes)	N1 25:75	$2.93^{a} \pm 0.65$
	N2 50:50	$3.00^{ab} \pm 0.82$
	N3 75:25	$4.09^{b} \pm 0.59$
P3 (90 minutes)	N1 25:75	$3.14^{ab} \pm 0.78$
	N2 50:50	$3.00^{ab} \pm 0.90$
	N3 75:25	$3.00^{ab} \pm 0.79$

Note: Different notations following the numbers indicate significant differences at α = 5%

4. Conclusion

This study suggests that steaming duration and pineapple peel-flesh extract ratios were found to influence the sensory quality of coffee processed with pineapple extract. Steaming for 30–60 minutes combined with a 75:25 peel-flesh ratio produced the most preferred brewed coffee by panelists, improving attributes such as color, aroma, body, acidity, and overall liking, while 90-

minute steaming reduces preference levels. A higher proportion of pineapple peel extract compared to juice resulted in higher preference scores than other treatments. These findings highlight the potential of pineapple extract as a natural processing ingredient to enhance coffee sensory quality, and further testing is recommended to refine processing conditions.

Abbreviations

No abbreviations were used in this manuscript.

Data Availability Statement

All images and data are available upon request.

Contribution of the Author

Wiwik Endah Rahayu: data curation, preparation, investigation, resources, and initial draft writing. **Desy Triastuti**: investigation, data curation, and resources. **Fenny Aprilliani**: supervision, conceptualization, and methodology. **Putri Citra Pratiwi**: supervision, conceptualization, and resources. **Jawad Ahmed Hasan**: supervision and conceptualization. **Kori Rahma Mardika**: investigation and resources.

Conflict of Interest Statement

The authors declare no conflict of interest or competing interests.

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